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# SIDE-BLOWN BESSEMER PROCESS IN THE PEOPLE'S REPUBLIC OF CHINA

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Metallurgists in the People's Republic of China are showing particular interest in the side-blown bessemer process for producing steel for rolling, while in Soviet and world practice, side-blown converters, especially with basic lining, are used primarily for producing steel castings.

Chinese metallurgists are presently producing nearly 15% of all steel in side-blown converters, and principally in the following plants, inspected by me:

| Plant | Shanghai | Ta-yeh | Tyan'-Shan [sic; probably the steelworks at T'ang-shan, Hopeh Province] |
|---|---|---|---|
| No of converters | 5 | 2 | 6 |
| Capacity (in tons) | 3.8 | 1.5 | 6 |
| Lining | Acid | Acid | Basic |
| Annual productivity (in 1,000 tons) | 100 | 50 | 200 |

Moreover, there are side-blown converters at plants in Chungking, where, apparently, about 100,000 tons of steel are produced annually.

The use of side-blown converters in China began during the Japanese occupation but reached maximum development in the People's Republic of China; moreover, the principal reasons for this development of small bessemerizing were insufficient scrap for organizing open-hearth production; independence of the blast-furnace shops; possibility of using up to 20% scrap in cupola furnaces; and presence of a certain reserve of ore for producing low-phosphorus cast iron.

At present, the use of side blowing, even in basic converters, is now being made; this permits the use of common open-hearth pig-iron, which is cheaper and less deficient then the bessemer iron.

## A. Steel Smelting Shop With Side-Blown Converters

The layouts of converter shops in the plants inspected were completely identical: all the technological and auxiliary equipment areas were situated parallel to the longitudinal axis of the main building (See Figures 1, 2, and 3).

Two or four cupola furnaces, depending on converter capacity, are located along the side of the shop building; the charging yard is situated in parallel. Skip hoists are used to load the cupola furnaces. The steel smelting shop building is 25 meters wide and is of various lengths, depending on the productivity.

Converters, with their firing chambers along the walls, are placed on the same line with the cupola furnace forehearths, which are situated inside the building.

Tapping is done in the pit, since the axes of rotation of the converters are at approximately floor level. Ladles for the converter steel and the cupola furnaces pig iron are installed in the pits. The shop bridge cranes have a lifting capacity of 20-25 tons; the medium cranes are used for charging the pig iron and other operations, while the extreme cranes are used for positioning molds, pouring steel, and removing ingots.

In each of the pouring runners (in the Tyan'-Shan plant there are nine of them) there is one group of 50-60 molds 1,300 mm high and with a cross section of 100 by 100 mm (ingot weight is 90 kg). Between the runners are placed platforms for the cleaning and lubrication of the molds, while between two groups of converters, there is a platform for packing the converters, and stand for pneumatic tamping of the lining (in the Shanghai plant) or for producing linings (in the plants in Ta-yeh and Tyan'-Shan), and a reserve supply of refractory materials. A separate department is also set aside for the repair and drying of ladles and stoppers.

## B. Smelting Pig Iron in Cupola Furnaces

Pig iron and scrap, previously prepared in relation to size, are charged into cupola furnaces; the coke used is comparatively coarse, and the limestone is sifted.

For converters with acid linings, low-phosphorus pig iron containing 1.43 - 0.73% Si, 0.95 - 0.80% Mn, 0.089 - 0.053% S and 0.04% P, is produced in cupola furnaces.

For converters with basic lining, pig iron containing 4% C, 0.92 - 1.15% Si, 1.7 - 2% Mn, 0.05% S and 0.3% P is smelted.

Cupola furnaces with a productivity of 8 tons per hour are placed in pairs so that two units may be used for one forehearth.

The pig iron poured into the converters has a temperature no higher than 1,300°, which leads to a great loss of metal in the converter, especially in rainy weather. The low temperature of the charged pig iron decreases the output of metal chiefly in the basic converters of the Tyan'-Shan plant, where the relative humidity of the air reaches 90%. A high number of rejects is caused not only by great loss, but also by short-run castings and slag inclusions.

## C. Converter Reduction

Converters have variable capacity, from 1.5 to 6 tons. The retort chamber of one of the converters is shown in Figure 4. Their axes of rotation are 0.5 m higher than the shop floor level.

Air compressors for the converters and ventilators for the cupola furnaces are located in a special building (See Figure 1); the air compressors have a productivity of 300 $m^3$ per minute at a pressure of 350 mm Hg and the ventilators, of 145 $m^3$ per minute at a pressure of 250 mm Hg (data of the Tyan'-Shan plant).

### 1. Blow Process

The blow of converters with an acid lining is no different from the usual, although comparatively "cold" chemical pig irons (1.0 to 1.2% Si) are used. This is because during the continuous operation of the converters, the loss of heat by radiation is diminished, which makes it possible to use pig iron with a comparatively lower silicon content.

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The operation of basic converters, however, has essential peculiarities.

If in the acid process, the duration of the blow does not exceed 15 to 20 min, then the basic converter is under blow for not less than 20 min, plus the time for two stops for delivery of clinkers and fluorspar and for drawing off slag (See Figure 5). The total duration of the basic process is 30 to 35 min, which is due to the small specific volume of the converter (0.6m3 per ton), the low initial temperature of the pig iron (not over 1,300°), and the significant total hydrogen, silicon, and manganese content; it is necessary to keep the blow in check because of ejections, as well as during the charging of lime and the drawing off of slag.

Owing to these reasons, the stability of the converter lining (particularly the basic linings) is very low, only from 30 to 65 heats. Therefore, for every converter in operation, there has to be one converter in the process of drying and two in the process of relining.

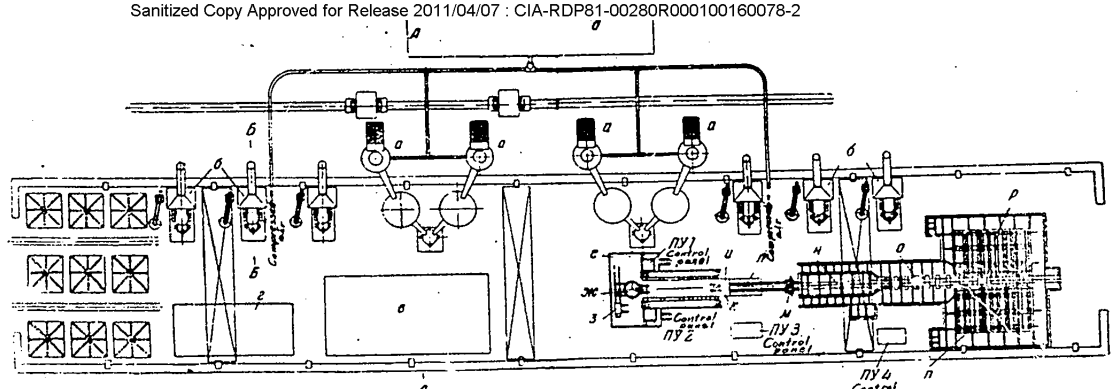


Figure 1. Location of Equipment in a Steel Smelting Converter Shop With a Casting Machine (cross-sections AA and ББ - in Figures 2 and 3) a - cupola furnaces; б - converters; в - department for drying ladles and packing converters; г - department for cleaning molds (to the left-pouring runners); д - compressor and ventilator; е - casting platform; ж - 50 ton ladle; з - reserve casting box; и - axis of the left crystallizer of the casting machine; к - id, right -; л - condenser; м - pusher; н - ingot cutter; о - roller conveyer; п and р - dragging devices for removing ingots.

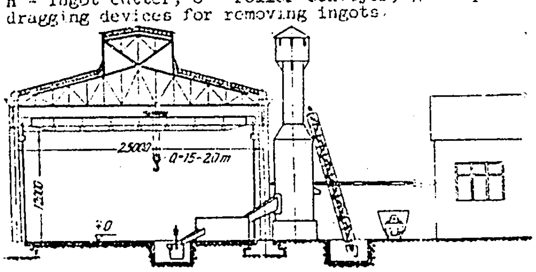

Figure 2. Cupola Furnace Installation (see cross-section AA Figure 1)

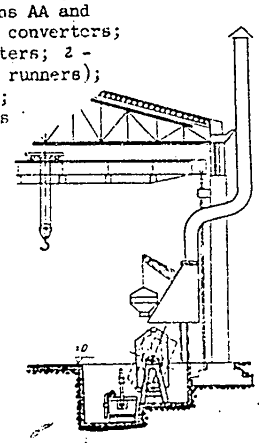

Figure 3. Converter Installation (see Figure 1,

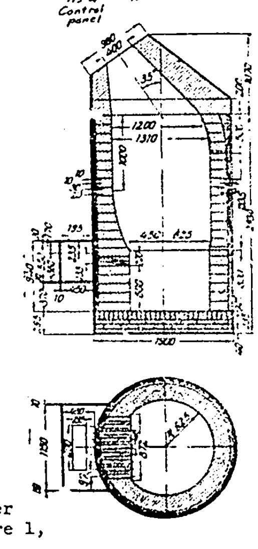

Figure 4. General Design of the Retort Chamber of a Converter

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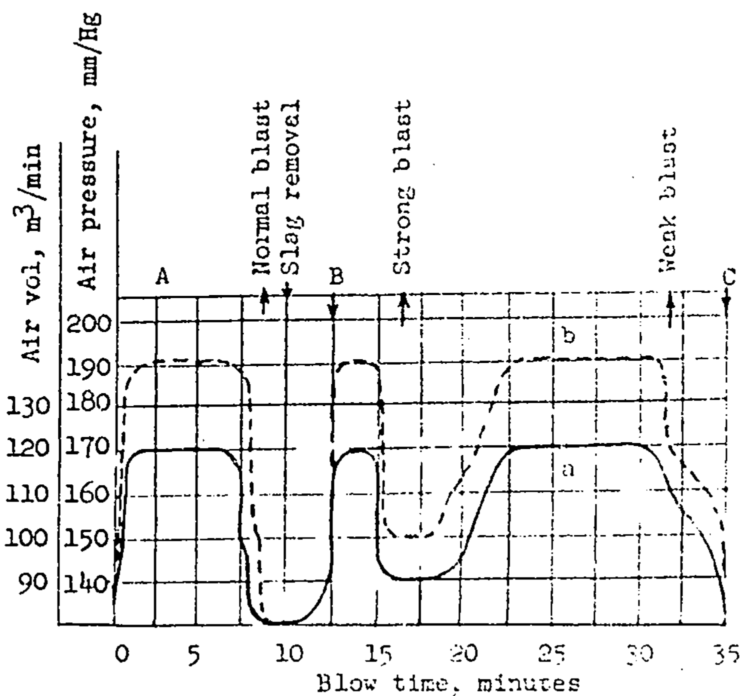


Figure 5. Change of Blow Volume (a) and Pressure (b) During the Blow Process: A - introduction of 2 kg/ton lime, 6 kg/ton clinkers, 1 kg/ton fluorspar; B - id, 40 kg/ton lime, 10 kg/ton clinkers, 2 kg/ton fluorspar; C - end of blowing.

The strong pitting of the lining leads to the contamination of the metal with slag inclusions.

The struggle against these difficulties is hampered by conditions which are present in the People's Republic of China: the Bessemer shops are forced to boost production at the expense of overloading the converters and cupola furnaces, which leads to a decline in output of top-grade metals and an increase in contamination (the consumption of pig iron per one ton of steel constitutes 1.3 tons).

2. Steel Pouring

Smeltings are ended with a carbon content of 0.06 or 0.10%. Prior to tapping into the ladle reducers are added: ferromanganese, ferrosilicon and 2 kg aluminum (2 kg aluminum are added also to the converter before tapping).

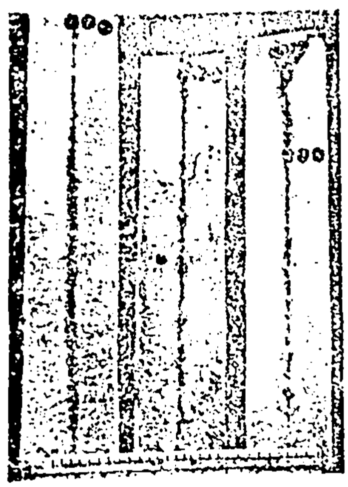

Figure 6. Shrinkage Flaws in an Ingot of Converter Metal

After the deoxidation of the steel the ladle is placed by a crane over the common central master mold of the [illegible]; since the fire-clay sleeve of the ladle has a 45mm diameter outlet, 6 tons of steel are poured in 2 min time; as a result of the ladle being placed [illegible] the converter, the extraction, pouring, and the release of the pit for the tapping of the slag takes only 12 min.

When pouring a group of 50-60 molds, the greatest risk is a cold heat. After pouring, ladles, as a rule, do not have scull, but the metal still does not always fill all the molds. With an increase in the weight of the ingots, for example up to 200 kg, it might be possible significantly to simplify the operation of the steel melting shop, but this is prevented by the characteristics of the existing rolling mills, which are almost completely manually operated.

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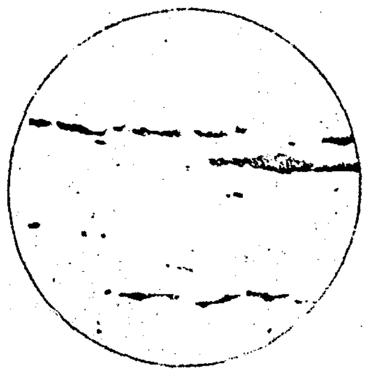

Figure 7. Slag Inclusions in an Ingot

Under these conditions, rimmed steel, in general, cannot be poured: with a full stream, it vigorously rises in the molds, and by intermittant opening of the stopper, it freezes. A change to a larger ingot would permit the successful handling of rimmed steel. However, ingots of killed steel under the pouring conditions described suffer large shrinkage and an increased number of slag inclusions (see Figures 6 and 7).

In spite of the pouring speed, it is the bottleneck in the process. Relining of the converters, which is performed around the clock, is the second bottleneck hindering production. For example, in the Tyan'-Shan plant, in the course of a day, two converters with a capacity up to 6 tons have to be lined; in Shanghai plant No I, one converter has to be lined per shift.

Both of these operations greatly hamper the production of a sound ingot: due to the low stability of the lining, the metal becomes contaminated with slag inclusions, and because of the high temperature of pouring, a deformed ingot suffers deep shrinkage cavities.

D. Characteristics of the Basic Shop

Formerly all converters of the People's Republic of China operated on acid lining; but in 1952, in the Tyan'-Shan plant, all converters were changed over to basic lining.

Materials for the lining of the converters of the Tyan'-Shan plant are prepared at the shop itself in a special building: shaped lining blocks are stamped from a mixture of dolomite and magnesite with pitch, which are then set in place in the converter shell, dried, and heated with a blast to the inner surface temperature of 800° to 1,000°. And the other plants are beginning to follow this example.

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The Tyan'-Shan plant, which was founded in 1943 and which was operated up to 1945 by a Japanese textile company, was formerly equipped with two electric furnaces and a 4-ton acid converter with two cupola furnaces of 8 tons each. After the Japanese capitulation, as was the case during the Japanese occupation, the Kuomintang output of metal remained insignificant. With the formation of the People's Republic of China, the duplex process was organized in the plant: an acid converter and an electric furnace. Later, the electric furnace was transferred to another plant, and in place of it, a converter was built. At present, the shop is comprised of six converters of 6 tons each and four 8-ton cupola furnaces with a general output up to 16 tons per hour. The productivity of the shop has grown in the following manner (thousands of tons):

| 1952 | 1953 | 1954 | 1955 (Plan) |
|---|---|---|---|
| 24 | 83 | 142 | 200 |

Pig iron, mostly with a high manganese content, coke, and lime serve as basic materials for the smelting. The steel yield from pig iron does not exceed 75% which is explained by the low temperature of the cupola cast iron, its high manganese content, and the losses during pouring.

With a converter capacity of 3.53 $m^3$, the melt weight of the liquid pig iron is 6-8 tons. Owing to the insufficient lifting power of the crane, the lining of the converter (magnesite and dolomite) has to be made very thin; therefore, the stability of the lining is low. Moreover, the low capacity of the converter and the thin lining aid in chilling the metal.

For reducing the ejection of the metal, the first stage blowing is conducted with a semisubmerged row of tuyeres.

The converter shop has apparently outgrown its basic parameters: increases in production are attained by reducing the economic and qualitative indices, for the improvement of which a change in shape and size of the ingot is necessary.

In connection with the rapid blowing process, the soaking of the steel before pouring constitutes only 3-3.5 min. The deoxidizing process should be considered as being unsatisfactory; a complex doexidizer is not used. Ferromanganese, ferrosilicon, and aluminum are fed directly into the ladle (in particular, aluminum -- 0.4 kg per ton). With a N content of 0.008 to 0.009 (sometimes 0.006%; more often, 0.011%), steel contains a great deal of oxygen, 0.06-0.09%, owing to the low carbon content at the end of the blowing.

The shrinkage cavities in the ingots are very large, which is due to bottom pouring and ingot deformity (100 by 100 by 1,400 mm).

## E. Basic Characteristics of the Process

The basic stages of the process in a side-blown converter are:

1. Immediate formation of a layer of metal oxides, principally iron oxides and a certain amount of silicon and manganese oxides, at the surface of liquid cast iron at the beginning of the blowing.

2. Subsequent oxidation of manganese and silicon in the metal covered by a layer of slag due to the oxygen in the iron oxide and not to the oxygen blast (as in a converter with bottom blowing); during this, the temperature of the metal quickly rises, owing to the heat generation by exothermic reactions. If this heat is not sufficient, an addition of ferrosilicon is necessary (the more the addition, the less carbon in the cast iron).

3. As the temperature of the bath is increased to 1,450°, rapid oxidation of the carbon into carbon monoxide begins, at the expense of the oxygen in the iron oxide, and later, due to the oxygen blast, changes to carbon dioxide.

The next distinction of the side-blowing process from ordinary Bessemerization with bottom blowing is the considerably greater heat generation, in the former from carbon oxidation, mostly into carbon dioxide.

As is known, it is possible to divide metal losses during blowing into chemical and mechanical. The chemical losses -- oxidation of iron, silicon, manganese, and carbon -- may be decreased by means of appropriate selection of cast iron composition; during prolonged blowing, they are greater than during short blowing. Iron losses depend on the composition and amount of slag. The duration of blowing depends on the content of elements in the cast iron requiring oxidation. Mechanical losses are proportional to the length of blowing and blowing intensity.

With a high iron oxide content, to insure slag equilibrium, a corresponding amount of silica from the lining is required. The shorter the blowing period, the better the lining is preserved.

There is a constant relationship between the carbon content of the cast iron and the temperature difference of the cast iron and the smelted steel. This relationship permits the fixing of the optimum carbon and silicon content in the cast iron and its initial temperature during charging into the converter for the production of high quality steel. The higher the initial temperature of the cast iron, the less the temperature difference; the smaller this difference, the less chemical energy the charged cast iron can have.

The relationship of the last two values should be more or less constant. According to data of the Iron and Steel Institute (published in "Report of the Bessemer Process"), for side blown acid converters, the temperature difference between the charged pig iron and resultant steel should be an average of 350°-400°, while the chemical heat of the exothermic reactions should correspond to an equivalent carbon content of 4.2 to 4.5% (relationship of the values is 83-89).

In the side-blown converter process, both acid and basic, as used in the People's Republic of China, it is expedient to attempt to increase the temperature of the charged pig iron, and, consequently, the smelted steel (these indices are interrelated). The use of chemically hotter pig irons will result in an increase of waste and reduced output of metal.

Enrichment of .e cupola furnace and converter blasts with oxygen should be accepted as the most rational method of increasing the temperature of metal. With an oxygen consumption of up to 25 $m^3$ per ton of pig iron, it is possible to obtain a good yield of high-quality metal.

The substitution of air blowing in the converter with commercially pure oxygen (from above) at a pressure of about 10 atm through a water cooled tuyere gives even better results. In this case, the oxygen consumption is 60 to 70 $m^3$ per ton of steel.

## F. General State of Steel Smelting Shops With Side-Blown Converters

In spite of the crowded conditions in the shops, the operation of the converters is well organized. All operations in cupola furnace and converter smelting, in the preparation and arrangement of runners, ladles, etc., are carried out precisely, quickly, and with uniform heating; in the shops, cleanliness is maintained.

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To liquidate the production bottleneck -- pouring the steel into the runners -- it is apparently necessary to change to mechanical pouring, using an inclined (shown in the schematic of the right half of the shop in Figure 1) or vertical aggregate. In both cases, the operation of the shop would be simplified, while the quality of the metal and output per annum would be increased by not less than 10%.

## Conclusions

"Little Bessemerizing," which has developed in the People's Republic of China, has prospects of further development and improvement if oxygen is used. To do this, the modernization of existing plants is the first thing to be done.

In the newly constructed plants in the People's Republic of China, in conjunction with the lack of domestic scrap, it is necessary to use Bessemer conversion with oxygen blowing in large volume converters, in both the simplex process, as well as in the duplex process.

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